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Development of a Plastic Stabilizer for the M865 Training Projectile

by James Garner,
Mark Bundy, and James Newill

ARL-MR-445

May 1999

19990708 160

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Army Research Laboratory

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Development of a Plastic Stabilizer for the M865 Training Projectile

James Garner, Mark Bundy, and James Newill

Weapons and Materials Research Directorate, ARL

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Abstract

The U.S. Army Research Laboratory (ARL) has fabricated and tested a preliminary version of an injection-moldable plastic M865 training round stabilizer assembly. This preliminary stabilizer (flare) is made from polyetheretherketone (PEEK) and is expected to handle the in-bore and out-of-bore aerothermal environments sufficiently to conform to the performance of the present M865 flare. A more refined flare assembly that matches physical properties of center-of-gravity location and weight, as compared to the present aluminum flare, can be engineered. A refined flare assembly will use a steel insert with the plastic flare section molded around it. Injection-molding a plastic flare promises several potential advantages. An entirely, or predominantly, plastic flare assembly can be produced at a significantly reduced cost. Injection-molding the flare should also reduce the variability typically associated with machined parts. The flares could also be manufactured more quickly.

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1. Introduction

Defense budget cuts mandate that the U.S. Army train more efficiently. Efficiency, in most cases, is measured in "bang for the buck." Systems that meet U.S. Army requirements at reduced cost are prime candidates for product-improvement programs. This philosophy extends down to the component level.

The current aluminum stabilizer (flare) for the M865 training projectile, fired from the M1 Abrams M256 cannon, costs approximately \$15 when purchased in quantity. Much of this cost is due to machining while meeting the tolerances given for the part. The flare provides the aerodynamic stabilization for the round and must withstand gun launch and flight loads. In addition, the flare must also be chemically compatible with the propellant bed. Producing a flare that meets these requirements and is less expensive could result in large peace-time dollar savings to the U.S. Army. The cost estimate to produce an injection-molded plastic flare appears to be conservatively \$10—and potentially less. The U.S. Army Research Laboratory (ARL), with support from the Close Combat Armaments Center, Picatinny Arsenal, NJ, has undertaken this effort.

2. Design Philosophy and Requirements

The present M865 flare is basically conical with slots milled at the rear to induce roll consistent with stable and accurate flight. A hollowed rear section reduces stabilizer weight and assists with tracer visibility. As the round slows during its flight, the high-drag characteristics of the flare take effect and thus limit the maximum range of the training projectile. To mimic this performance, a replacement flare for the M865 requires the same exterior geometry and weight.

The proposed plastic flare appears is an ideal candidate to meet these needs. The flare configuration is more accurately described as a combination of an extended metal stud and an injection-molded plastic flare. Figure 1 shows a simplified schematic section of the first design.

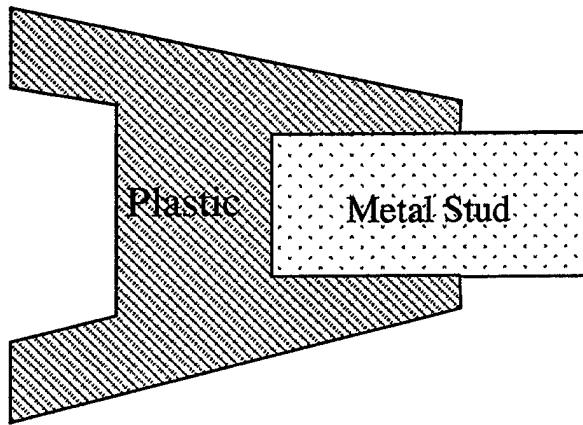


Figure 1. A Simplified Schematic of a Proposed M865 Flare Assembly.

The metal stud is used to provide a strong connection to the flight body. A metal stud with an injection-molded plastic flare surrounding it is far less complicated to fabricate, more consistently produced, and less expensive. Much of the expense in the production of the current aluminum flare is machining to part tolerances. A modified stud, not shown in Figure 1, uses a hollowed rear to serve as a tracer well and is planned for a future improved design. The stud mass of metal provides a ready heat sink for the heat generated by the tracer. The final, and perhaps most obvious, purpose of the metal stud is to increase the flare weight to bring it back to standard aluminum part weight.

A plastic flare must survive the high-temperature flight environment, as well as the high-pressure high-temperature gun launch. These two regimes present very different challenges for the flare. Prior test measurements have shown that in-flight temperatures on the aluminum flare are 500–550 K (Stumpfel 1996). A heat-resistant plastic must be chosen accordingly to meet this challenge. Some commercially available plastics have heat-distortion temperatures above this temperature (Ash and Ash 1992). The least-understood criterion is the in-bore requirement for the flare. In bore, the flare is subjected to intense heat (1,920 K) and pressures on the order of 330 MPa. Fortunately, these conditions only last for a portion of the 6-ms-bore travel time. This time is insufficient for substantial pyrolyzation of the flare (Bundy 1996). The pressure and acceleration effects are more immediate and appear to dominate the material choice

for in-bore and transitional (just out of bore) conditions. The material must also survive severe acceleration loads.

3. Testing and Analysis

Firings were performed to attempt to evaluate polyetheretherketone (PEEK) as a flare material. This material was chosen since it had performed well in past tests as a fin material for an M735 projectile. Prior testing showed PEEK resin to be flexible enough, such that fins of this material bent but remained intact throughout the flight. One of the conclusions from this past test was that the plastic material chosen should be strong, but not too stiff, in order to avoid material fracture. Data were obtained only for short ranges (about 0.2 km). The flare test was designed to gather data in the same regimes (in-bore and transitional ballistic). The transitional ballistic environment muzzle blast produces large pressure gradients and must be considered in any stabilizer design.

Four firings of the proposed design were conducted at the Transonic Experimental Facility (TEF) of Aberdeen Proving Ground (APG). After each firing, the flare broke off and fractured into several pieces near (approximately 10 m) the gun muzzle (see Figure 2). A photograph of the flare model before firing and a recovered piece of a fired flare indicate that it failed in shear along a conical surface from the base of the stud cavity to the hollowed flare base. Figure 3 shows the hypothesized failure lines on a section view of the flare. The small recovered core (shown in Figure 4) has a circular base that corresponds almost exactly to the diameter of the flare at the base of the hollowed area.

A finite element model of the plastic flare was created to better understand why the design was failing and what changes were needed to halt this failure. An Ansys* finite element model

* Version 5.4, Swanson Analysis Systems, PO Box 65, Johnson Rd., Houston, PA 15342.

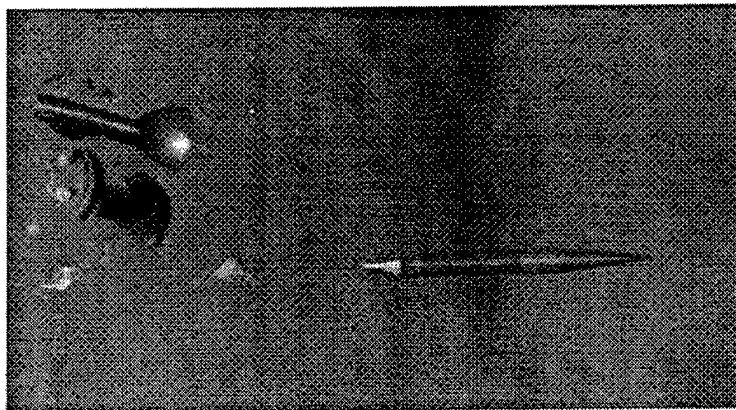


Figure 2. High-Speed Photograph of the Initial M865 Plastic Flare Design.

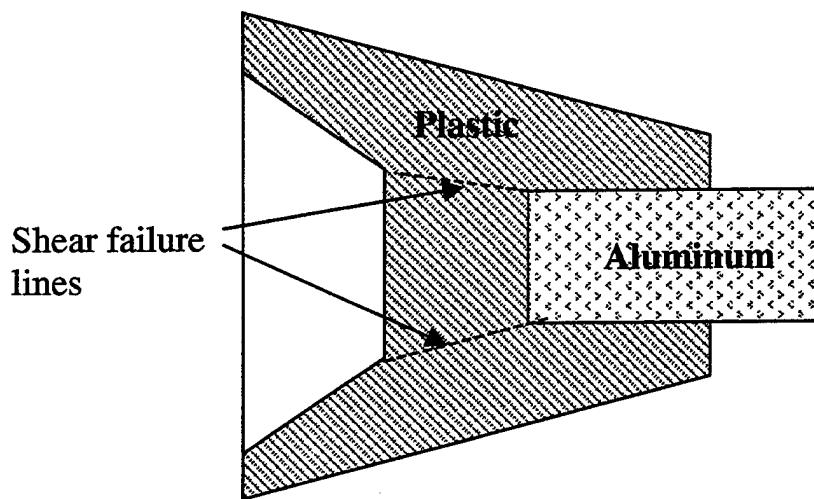
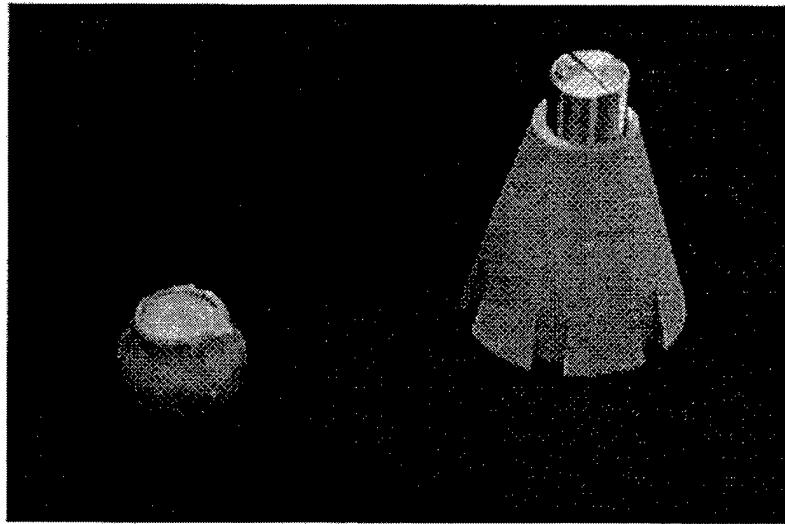


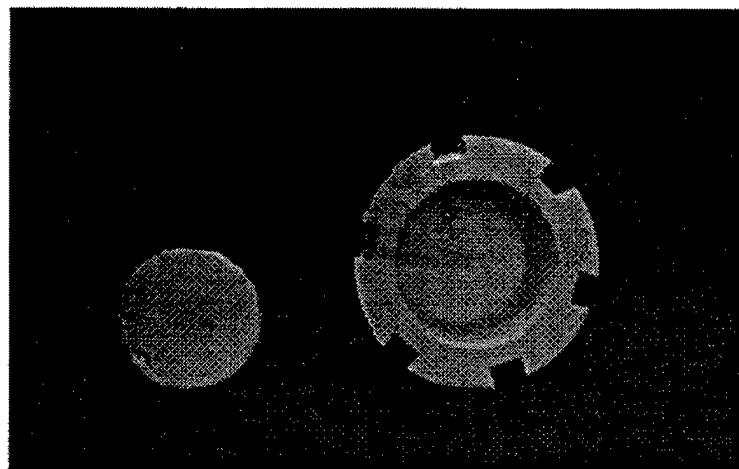
Figure 3. Hypothesized Failure Lines on the Initial M865 Plastic Flare Design.

calculated to match those occurring in bore. Figure 5 shows the Von Mises stress contours on the rear portion of the flare that result due to the in-bore pressure and acceleration conditions. One theory is that the flare failed in bore.

The next flare model fired had modifications based on the examination of the recovered part geometry and the results of the stress analysis. The hollowed flare section was filled, and the



(a) Side View.



(b) End View.

Figure 4. Views of Recovered Piece and Original.

aluminum connection stud was extended the entire length of the flare. Both of these modifications actually simplified the flare design and manufacture. Again, a simplified version of the design is shown in Figure 6. Filling the base creates a slight drag increase, but trajectory simulations indicate that the round will still be a ballistic match over the ranges of interest. The stud cavity was extended the length of the flare, but the aluminum stud was positioned just short

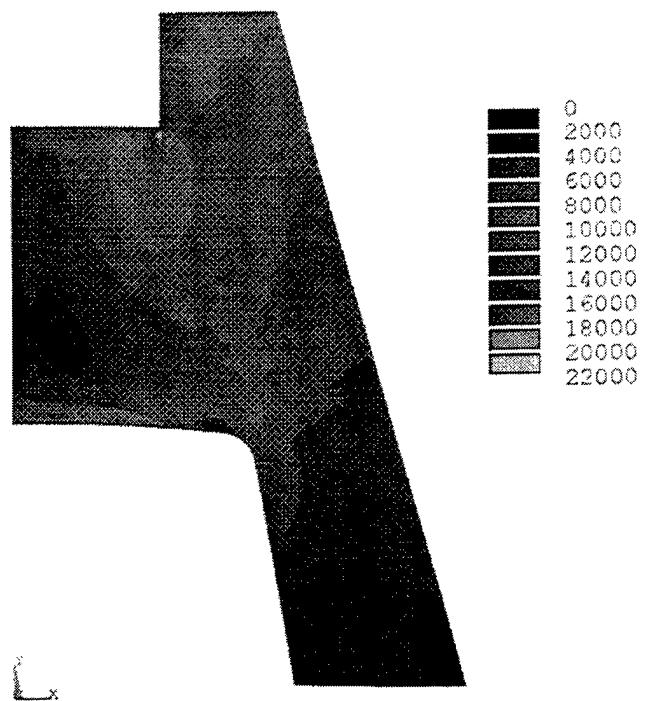


Figure 5. Flare Stress Analysis Results (psi) Under Acceleration and Hydrostatic Loading.

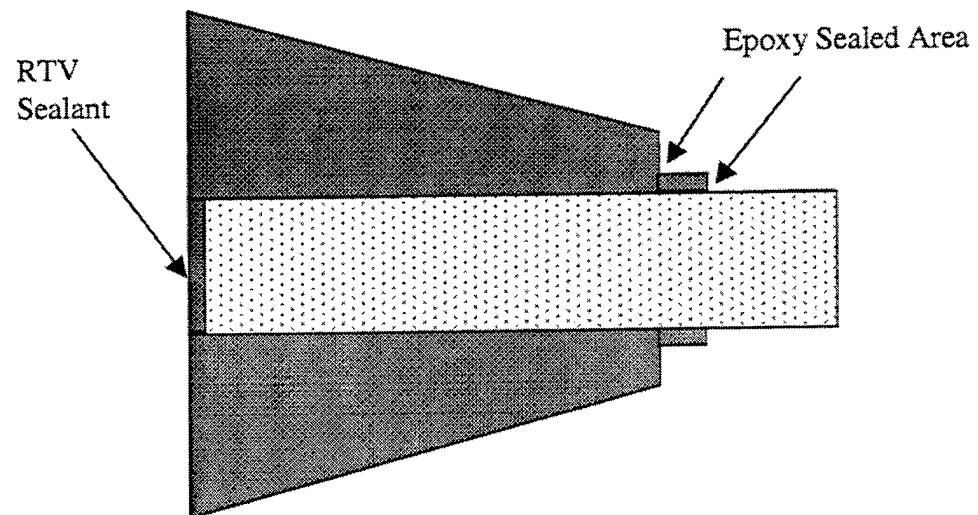


Figure 6. Schematic of Improved Plastic M865 Flare Design.

of the flare base. A room-temperature-vulcanizing (RTV) sealant was inserted into this slight recess to prevent gun gasses from penetrating between the stud and the plastic flare. Gas infiltration at this joint would likely produce severe damage.

The firing results were far more promising with the improved flare design. Two projectiles using this flare were fired. The first round flare fractured, but the flare pieces were large as opposed to the small pieces of the flares from the initial test series. The second firing was a complete success, as shown in the high-speed photograph of Figure 7. A circular impact hole in a yaw card confirmed that the entire flare was present and intact. It is believed that the first flare in the second series failed because there was no sealant at the stud/penetrator/plastic interface. A theory assumes that the rearward displacement of the PEEK flare due to acceleration caused a gap between the projectile and the flare front. This gap was immediately filled by high-pressure gas. Once the round exited the bore, the high-pressure gas escaped and caused the flare to fail. The sealant at this joint used on the second round is thought to be responsible for stopping the penetration of high-pressure gun gas. An epoxy sealant was used at this interface.

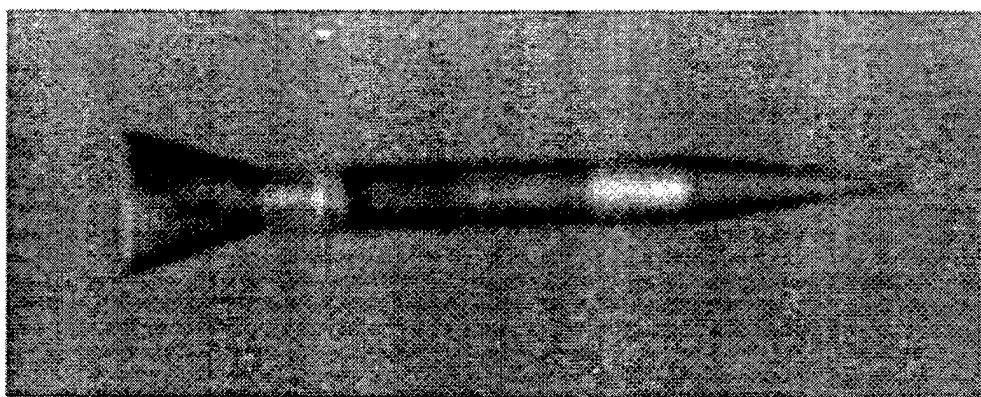


Figure 7. In-Flight Photo of M865 With a Plastic Flare.

4. Conclusions

Injection-molding the flare around a metal stud is an inexpensive alternative solution to the current flare design. Both trapped high-pressure gasses at shot exit, and in-bore acceleration

forces pose severe threats to the success of a plastic flare. In-bore heating does not appear to be a challenge, as relatively little of the flare material is pyrolyzed in the relatively short in-bore exposure time. Adverse aerothermal heating effects are also expected to be negligible, since the temperatures measured in flight are at or below the distortion temperatures for some plastics. This has not been experimentally demonstrated for longer range flights (>2 km). A successful near-field firing of a second-generation design was achieved using PEEK as the flare material. Investigating other plastic material choices and refining the design are the next logical steps in the development of the plastic flare. This testing offers a preliminary validation for the use of polymer plastics as a flare material and suggests that their dynamic properties make them suitable for expanded use.

5. References

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</p>			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED	
	May 1999	Final, Oct 98	
4. TITLE AND SUBTITLE		5. FUNDING NUMBERS	
Development of a Plastic Stabilizer for the M865 Training Projectile		1L162618AH80	
6. AUTHOR(S)		7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	
James Garner, Mark Bundy, and James Newill		U.S. Army Research Laboratory ATTN: AMSRL-WM-BC Aberdeen Proving Ground, MD 21005-5066	
8. PERFORMING ORGANIZATION REPORT NUMBER		9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)	
ARL-MR-445			
10. SPONSORING/MONITORING AGENCY REPORT NUMBER		11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT		12b. DISTRIBUTION CODE	
Approved for public release; distribution is unlimited.			
13. ABSTRACT (Maximum 200 words)			
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14. SUBJECT TERMS		15. NUMBER OF PAGES	
plastic fins, manufacturing, cost savings		15	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
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